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QUALIFICATION TEST AND FINAL PROGRAM REPORT

Volume 1

FOR
SAFETY AND ARMING DEVICE
MSFC PN 10A00465
TMC/S PN 816780

FOR

SPACE SHUTTLE SOLID ROCKET BOOSTER
(NASA-CR-150791) QUALIFICATION TEST FOR
SAFETY AND ARMING DEVICE MSFC PN 10A00465
TMC/S PN 816780 FOR SPACE SHUTTLE SOLID
ROCKET BOOSTER, VOLUME 1
(Teledyne/McCormick Selph, Hollister, G

N78-31159

G3/20 Unclass
29134

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TABLE OF CONTENTS
SECTION 1

<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE</u>
1.0	INTRODUCTION	1
2.0	SCOPE	2
3.0	DESIGN AND DEVELOPMENT	3
3.1	DESIGN	3
3.2	DEVELOPMENT	3
3.2.1	STRUCTURAL INTEGRITY TESTS	4
3.2.2	EXPLOSIVE CHARGE PERFORMANCE MARGIN TESTS . . .	4
3.2.3	FULL SCALE S&A TESTS	6
3.2.4	PROBLEMS AND CORRECTIVE ACTIONS	6
4.0	FABRICATION AND LOT ACCEPTANCE TEST	8
4.1	FABRICATION	8
4.2	LOT ACCEPTANCE TEST	8
5.0	QUALIFICATION TESTING	12
5.1	TEST SUMMARY	12
5.2	TEST SEQUENCE AND RESULTS	12
5.3	PYROTECHNIC INITIATION CONTROLLER (PIC) AND CONTROL PANEL	19
5.4	TEST MALFUNCTIONS	19
5.4.1	SPECIMEN NUMBER 2	19
5.4.1.1	DESCRIPTION OF MALFUNCTION	19
5.4.1.2	EVALUATION	20
5.4.1.3	CONCLUSION AND CORRECTIVE ACTION	21
5.4.2	SPECIMEN NUMBER 14	21
5.4.2.1	DESCRIPTION OF MALFUNCTION	21
5.4.2.2	EVALUATION	22
5.4.2.3	CONCLUSION	25
5.4.2.4	CORRECTIVE ACTION	25
5.4.3	SUMMARY	25
5.5	PROGRAM SYNOPSIS AND CONFIGURATION	26
5.5.1	PROGRAM SYNOPSIS	26
5.5.2	CONFIGURATION	27

TABLE OF CONTENTS
(Continued)

<u>TABLES</u>	<u>TITLE</u>	<u>PAGE</u>
I	DEVELOPMENT TEST SUMMARY	5
II	LOT ACCEPTANCE TEST SUMMARY	11
III	QUALIFICATION TEST SUMMARY	13

<u>APPENDIX</u>	<u>TITLE</u>	<u>PAGE</u>
A	PHOTOGRAPHS	28

PREFACE

The work described in this report was performed by Teledyne McCormick Selph (TMc/S) at our facility at Hollister, California for NASA-MSFC under contract NAS8-31973 between June 1976 and May 1978.

This document is a combined qualification test and final report of a program to design, develop, and qualify a Safety and Arming Device for the space shuttle Solid Rocket Booster. It is submitted as documentation Item Number 13 of Table VII of MSFC Specification 10A00465 Revision C and the "Final Report" as described under Reports Requirements in Scope of Work, Exhibit "A" to Contract NAS8-31.73. It is presented in two volumes. Volume I consists of the narrative program description (Section I) and qualification testing laboratory report (Section II). Volume II contains copies of the following documents which were submitted to and approved by MSFC at the required time throughout the program:

Development Test Report - Number 4918-2 Rev. B

Lot Acceptance Test Report - Number 4918-246 Rev. A

Development Test Procedure - Number DTP 816780 Rev. A

Lot Acceptance Test Procedure - Number ATP 816780 Rev. B

Qualification Test Procedure - Number QTP 816780 Rev. A

The subject program was conducted in five phases identified as:

- Phase I Material Study and Prototype Design
- II Prototype Fabrication, Development Testing, and
 Final Design
- III Fabrication
- IV Lot Acceptance Test
- V Qualification

This comprehensive report is concerned with all aspects of the program from prototype design to qualification. Phases I through IV of the program were thoroughly covered in earlier reports which are included for reference as volume II of this report. However, these phases will be reviewed and the most pertinent facts discussed herein.

Therefore this report emphasizes the qualification phase of the program not previously reported. Areas discussed include:

- description of tests and results
- test malfunctions, their cause and corrective action
- configuration
- test data sheets (section II)

3.0

DESIGN AND DEVELOPMENT

3.1

DESIGN

The basic design for this Safety and Arming (S & A) Device was a similar device assembled by TMc/S and used on the SATURN Program. Several modifications were made to the earlier design to make it compatible with the more severe requirements of the Space Shuttle SRB application. These included:

Modification of the body to enable it to withstand the high output of the NSI detonators without fragmenting or allowing the detonators to be ejected.

Redesign of the explosive transfer charge to minimize charge weight.

Redesign of the switch actuator to minimize component mass and make the device less susceptible to autorotation of the rotor during dynamic environments.

The validity of these modifications has been shown by the absence of these failure modes during development and qualification testing.

3.2

DEVELOPMENT

During the development phase of the program special test hardware and full scale S & A devices were assembled and tests performed which emphasized structural integrity of the body and rotor, explosive charge performance margins, and full scale S & A device performance after dynamic testing. A comprehensive development report Document Number 4918-2 was submitted and approved at the

3.2 DEVELOPMENT (Continued)

completion of the development phase. It is included in Volume II of this report. However, the salient points will be reviewed herein and the configurations, tests, and results summarized in Table I.

3.2.1 Structural Integrity Tests

This test was performed on two units to demonstrate that the S & A body could withstand the explosive output of two NSI detonators fired simultaneously without fragmenting or expelling the detonators. The test hardware was an S & A body containing the sealing sleeve, a rotor with explosive transfer charges installed, and PN 10A00487 Debris Shield installed. Rotors were placed in the SAFE position and both detonators fired simultaneously.

There was no fragmentation of the body and the detonators remained in place.

3.2.2 Explosive Charge Performance Margin Tests

Forty-five (45) pieces were fired in six groups. The test hardware consisted of single port bodies, sealing sleeves, and rotors with explosive charges installed. MSFC furnished NSI detonators and CDF lines were utilized. Parameters tested were gaps at explosive interfaces, transfer charge over and under load, low temperature, and angular misalignment of the rotor.

All test groups were successful in meeting the desired performance limits. Data analysis indicated a very wide margin of reliable performance with regard to rotor misalignment, 99.9% reliability at 25°.

TABLE I

TEST DESCRIPTION	NO. TESTS	HARDWARE DESCRIPTION	TEST PARAMETER	RESULTS
Structural Integrity Test	2	Body with sleeve, rotor with explosive leads, NSI detonators, CDF lines	Strength of body with high output NSI detonators fired	Bodies and rotors intact, detonators not ejected
Explosive Train Tests		Test body with sleeve, rotor with explosive lead (1), NSI detonator, CDF line		
Group I	5		Control group - nominal config.	Detonation Xferred, CDF lines initiated, cores consumed
Group II	5		.060 detonator standoff, -65°F	Explosive leads initiated, CDF lines initiated, cores consumed
Group III	5		Worst case explosive lead to CDF and tip standoff was .060	Explosive leads initiated, CDF lines initiated high order
Group IV	5		Explosive lead 10% underload	CDF leads initiated high order
Group V	5		Explosive lead 10% overload	CDF leads initiated high order, no fragmentation of body or rotor
Group VI	20		Angular misalignment of rotor to body	Reliability of firing is 99.99 at 95% CF for 22.63° misalignment, probability of not firing is 99.99 at 95% CF for misalignment of 48.5° or 41.5° safety margin in SAFE position
Full Scale S&A Tests		Complete S&A to expected qual configuration	Operational tests and SAFE, and ARM firing with basic environmental conditioning	
Group I	2		Low temperature function ARMED	CDF lines initiated high order, witness tubes fragmented
Group II	2		High temperature function SAFE	No decomposition of CDF test leads, body and rotor intact, detonators not expelled

DEVELOPMENT TEST SUMMARY

ORIGINAL PAGE IS
OF POOR QUALITY

3.2.3 Full Scale S & A Tests

Four (4) complete S & A devices were assembled. They were subjected to the non-destructive acceptance tests, sine and random vibration and the complete shock spectrum. Two devices were fired at low temperature ARMED and two at high temperature SAFE. These test units were completely successful with respect to firing in the SAFE and the ARMED positions. The ARMED firings caused high order propagation of the CDF lines as evidenced by fragmentation of the witness tubes. For the SAFE firings the CDF test leads were not initiated, the body and rotor remained intact, and the detonators were not ejected. The 10A00487 Debris Retainers remained in place on the SAFE position firings with no indication of separation.

3.2.4 Problems and Corrective Actions

During assembly and test of the full scale development units deficiencies arose with regard to:

- (a) Failure of the monitor switches to actuate within 7.5° of rotor rotation.
- (b) Overtravel of the rotor (beyond 90°) at 32 vdc
- (c) Leakage at the housing to body interface.

These deficiencies were found to be related to improper fit of components or inadequate assembly and adjustment instructions. The corrective actions were to:

- (d) Adjust switch position to achieve the 7.5° actuation and add 100% Q.C. verification.
- (e) Modify the detent to increase travel to prevent over-rotation at 32 vdc.
- (f) Modify housing and body dimensions to obtain closer fit.

3.2.4 Problems and Corrective Actions (Continued)

These corrective actions were subsequently incorporated into the qualification lot of S&A devices and appear to have been completely effective in preventing re-occurrence of the deficiencies experienced on the development units. The design was approved for phase III fabrication of the qualification lot.

4.0 FABRICATION AND LOT ACCEPTANCE TEST

4.1 FABRICATION

The next phase of the program was to fabricate a lot of sixteen (16) S&A devices, fourteen (14) live units for qualification testing, and two (2) inert units for delivery to MSFC.

The fabrication sequence was completed without major incidents. However, deficiencies which appeared later during acceptance testing were found to be related to marginally acceptable adjustments made during assembly.

4.2 LOT ACCEPTANCE TEST

During acceptance testing the examination of product, x-ray, n-ray, vibration, and leak tests were completed without incident. However during electrical cycling tests six (6) of sixteen (16) units failed to actuate properly when 24 vdc was applied with the units conditioned to +165°F. This combination was the worst case condition of solenoid torque available to actuate the device; lowest input voltage and highest solenoid winding resistance due to temperature effect. Under these conditions solenoid torque was not sufficient to achieve reliable operation.

The defective devices were disassembled, various inspections and tests were performed, and assembly procedures were reviewed. The conclusion was that the most probable cause of the malfunctions was:

1. The return spring force of the solenoids was greater than allowed by the drawing. The net effect was to reduce the torque output of the solenoids. Spring force was not measured by TMC/S when the solenoids were received allowing deficient parts into the production area.

2. During initial assembly the S & A devices were tested for operation down to 24 vdc at room temperature with no allowance made for decreased performance due to temperature effects. However resistance measurements showed an 18% increase in resistance of the solenoid windings at +165°F which would have had a corresponding reduction in torque.

Solenoid return springs were reset to the correct value and a resulting torque increase was confirmed. The S & A devices were reassembled, adjusted, and operation verified at +165°F and +20°F (the operating temperature extremes) before the units were resealed. The complete acceptance test sequence was repeated including acceptance vibration. These reworked units met all test requirements and operated properly at the voltage and temperature extremes.

One other defective unit, Specimen Number 13, was found after acceptance vibration. This unit actuated properly at all voltage levels but no reading was from the voltage monitor circuit. Circuitry checks indicated and subsequent disassembly confirmed an open circuit due to a broken lead wire. The wire, broken at pin "N" of the connector appears to have been caused by a combination of insufficient wire length and improper routing of the wire bundle.

The broken leadwire from pin "N" of the connector to terminal "E4" was slightly short compared to the remaining wires. In addition the wire bundle was routed improperly when the housing was installed. This caused excessive stress to be applied to all the solder connections particularly to pin "N" of the connector. Re-examination of the N-Ray film confirmed these conditions had existed but were overlooked when N-Ray films were examined.

The loose wire was resoldered and the device re-assembled with particular attention paid to routing of the wire bundle to prevent stressing the wire connections. This unit passed all re-examination and repeat of the acceptance test program without further problem. A correction to the wiring instruction in the job history file (TMC/S supplementary records maintained in work area) will provide additional slack on this particular wire on all further units and N-Ray examination will verify proper routing of the wire bundle.

Acceptance testing was therefore complete and the lot ready for qualification testing. A summary of acceptance test results are presented in Table II and the lot acceptance laboratory test report is included in Volume II of this report.

TABLE II

Unit Number	Serial Number	Exam of Product 4.4.2.1	X-Ray 4.4.2.2	N-Ray 4.4.2.2	Acceptance Vibration 4.4.2.4	Leakage 4.4.2.4	Temperature Electrical Cycling 4.3.11	Ambient Temperature Electrical Checkout 4.4.2.5	Remarks
1 (1)	0007	X	X	X	X	X	X	X	No test anomalies
2 (1)	0015	X	X	X	X	X	X	X	No test anomalies
3	0005	X	X	X	X	X	O	*	Failed to actuate properly at 24 Vdc @ +165°F
	Unit Reworked	X	X	X	X	X	X	X	All tests acceptable after rework
4	0006	X	X	X	X	X	X	X	No test anomalies
5	0008	X	X	X	X	X	X	X	No test anomalies
6	0009	X	X	X	X	X	O	*	Failed to actuate properly at 24 Vdc @ +165°F
	Unit Reworked	X	X	X	X	X	X	X	All tests acceptable after rework
7	0010	X	X	X	X	X	X	X	No test anomalies
8	0011	X	X	X	X	X	O	*	Failed to actuate properly at 24 Vdc @ 165°F
	Unit Reworked	X	X	X	X	X	X	X	All tests acceptable after rework
9	0012	X	X	X	X	X	X	X	No test anomalies
10	0013	X	X	X	X	X	O	*	(1) Failed to actuate properly at 24 Vdc +165°F, (2) Exceeded 3.0 amperes at 32 Vdc @ +20°F
	Unit Reworked	X	X	X	X	X	X	X	All tests acceptable after rework
11	0014	X	X	X	X	X	X	X	No test anomalies
12	0016	X	X	X	X	X	X	X	No test anomalies
13	0017	X	X	X	X	X	O	*	Failed to actuate properly at 24 Vdc @ +165°F
14	0018	X	X	X	X	X	X	X	No test anomalies
15	0019	X	X	X	X	X	O	*	No voltage indication due to broken wire but unit actuated properly
	Unit Reworked	X	X	X	X	X	X	X	All tests acceptable after rework
16	0020	X	X	X	X	X	O	*	Failed to actuate properly at 24 Vdc @ 165°F
	Unit Reworked	X	X	X	X	X	X	X	All tests acceptable after rework

(1) Units 1 (SN 0007) and 2 (SN 0015) were inactive (inert) devices shipped to MSFC after tests completed.

"X" Indicates test passed

"O" Indicates test failed - see remarks

"*" Indicates test not performed due to failure at previous test

Reference paragraph per MSFC Specification 10A00465

LOT ACCEPTANCE TEST SUMMARY

5.0

QUALIFICATION TESTS

5.1

TEST SUMMARY

Fourteen (14) S&A devices, Type I, Series C configuration were subjected to the test program shown on Table III. TMC/S laboratory report number 4918-245 included as Section II of Volume I of this report contains the detailed test data sheets.

Two irregularities which occurred during the dynamic testing will be discussed in detail. One was an apparent switch failure during ordnance shock on specimen number 14 and the other was an electrical cycling malfunction on specimen number 2 after vibration. These two units were investigated, interim corrections were made, and the units returned to the lot. All units were fired successfully completing qualification.

5.2

TEST SEQUENCE AND RESULTS

- (a) Non-Destructive Acceptance (14 units) This was the lot acceptance testing discussed in paragraph 4.2 of this report.
- (b) Thermal Shock (14 units) Devices were exposed alternately to four hour cycles of +165°F and -70°F for a total of four high temperature exposures and three low temperature exposures. No post environment operational tests were performed. Visual examination revealed no apparent damage or deterioration.
- (c) Salt Fog (14 units) - The units were exposed to salt fog at 95°F for 48 hours. No post environment operational tests were performed. Visual examination revealed no apparent damage or deterioration.

TABLE III

Specimen No.	Serial No.	Acceptance 4.4.2	Thermal Shock 4.3.3	Salt Fog 4.3.4	Sinusoidal Vibration 4.3.6	Mission 1 4.3.6	Mission 2-6 4.3.6	Mission 7-10 4.3.6	Mission 1 4.3.6	Mission 2-6 4.3.6	Mission 7-10 4.3.6	Shock 4.3.9	Temperature-Humidity 4.3.8	Leak Test 4.3.7	Electrical Checkout 4.3.10	Temperature Electrical Cycle 4.3.11	Low Temp. Function ANNEX 4.3.12	Low Temp. Function SAFE 4.3.13	High Temp. Function ANNEX 4.3.14	High Temp. Function SAFE 4.3.15	Remarks
1	0005	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	X	-	-	-	rotor overtravel at 32 Vdc after random vibration
2	0006	X	X	X	X	O	-	-	-	-	-	-	*	*	X	X	X	-	-	-	
3	0008	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	X	-	-	-	
4	0009	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	-	X	-	-	
5	0010	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	-	X	-	-	
6	0011	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	-	-	X	-	
7	0012	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	-	-	X	-	
8	0013	X	X	X	X	X	-	-	-	-	-	-	X	X	X	X	-	-	X	-	
9	0014	X	X	X	X	X	-	-	X	-	-	-	X	X	X	X	-	-	-	X	
10	0016	X	X	X	X	X	-	-	X	-	-	-	X	X	X	X	-	-	-	X	
11	0017	X	X	X	X	X	X	-	X	X	-	-	X	X	X	X	-	-	X	-	
12	0018	X	X	X	X	X	X	-	X	X	-	-	X	X	X	X	-	-	X	-	
13	0019	X	X	X	X	X	X	X	X	X	X	-	X	X	X	X	X	-	-	-	
14	0020	X	X	X	X	X	X	X	O	*	*	*	*	*	X	X	X	-	-	-	switch malfunc- tioned during ordnance shock

"X" Indicates test performed and passed

"O" Indicates test failure/irregularity - refer to text

"*" Indicates test not performed due to failure on previous test

△ Acceptance testing as described in 4.2 of this report

△ Electrical checkout was performed after this environment

△ Reference paragraph per MSFC Specification 10A00465

QUALIFICATION TEST SUMMARY

- (d) Sinusoidal Vibration (14 units) - The test consisted of one sine sweep in each of three axis at a rate of 3.0 octaves per minute, with devices in the ARMED position. Frequency and test levels were:

5 - 10 Hz	± 1.0 g
10 - 40 Hz	± 1.7 g

During vibration rotor position was monitored to verify the rotors of the devices did not rotate more than $\pm 7.5^\circ$ from the zero position using an indicator lamp monitoring module connected through the input connector to the monitor switch circuits. The units were cycled from ARM to SAFE to ARM and back to SAFE after this test. There was no indication of autorotation during vibration and the units operated properly after the test.

- (e) Random Vibration (14 units) - Each device was subjected to three random vibration spectrums representing lift-off, boost, and re-entry phases of a typical flight. The lift-off and boost spectrums were applied with the devices in the ARMED position and the re-entry spectrum applied in the SAFE position. All fourteen units were vibrated for a time duration defined as mission 1. Specimens 11-14 were further vibrated through all three spectrums for an additional duration defined as missions 2-6 and specimens 13-14 vibrated still again for a duration defined as missions 7-10. The complete vibration schedule was as shown on Table II of MSFC Specification 10A00465.

S&A rotor positions were monitored during the test using the indicator lamp module. There was no indication of rotor autorotation on any of the units. Thirteen (13) of fourteen (14) units met all test requirements. However during post vibration electrical checkout specimen number 2 failed to operate properly as mentioned in the summary of paragraph 5.1. The analysis, cause, and corrective action relative to this unit is discussed in paragraph 5.4.1 of this report.

- (f) Shock (6 units) - The devices were subjected to three shock programs: (1) Ordnance Shock, (2) SRB water handling, and (3) SRB Parachute Deployment. Specimens 9-14 were subjected to two impacts (one in each direction) in each of three axis which is defined as mission 1 duration. The complete program was repeated on specimens 11-14 with 10 impacts per axis (mission 2-6) and repeated again on specimen 13 for an additional 8 impacts per axis (mission 7-10). All testing was performed with the device in the SAFE position. Rotor position was monitored as in vibration testing. The complete program was in accordance with Table IV of MSFC Specification 10A00465.

Testing was completed on specimens 9-13 without incident. However specimen number 14 failed to operate (rotate from SAFE to ARM position) after the first ordnance shock impacts were applied. Analysis, cause, and corrective action relative to this unit will be discussed in paragraph 5.4.2 of this report.

- (g) Temperature-Humidity (12 units) - The S&A devices were subjected to a 240 hour temperature - humidity cycle with temperatures between 82° F and 165° F and humidity of 85% to 95%. Twelve of the fourteen units in the qualification lot were subjected to this test. Since the environmental seals on specimens 2 and 14 had been broken during investigation of the deficiencies described above these two units were omitted from T&H and leakage tests.

At the conclusion of the exposure period the units were visually examined. There was no evidence or corrosion, peeling, chipping or blistering.

- (h) Leak Test (12 units) - The S&A devices (less specimen numbers 2 and 14) were subjected to a water emmersion type leakage test at a pressure of 1 psia (61,000 feet) for two minutes. There was no indication of leakage.
- (i) Electrical Checkout (14 units) - The S&A devices were subjected to ambient temperature electrical checkout consisting of: (1) ninety (90) degree rotation at 24, 28, and 32 Vdc, (2) contact voltage drop, (3) ARM and COMMAND switch position checks, (4) solenoid resistance measurement, (5) insulation resistance, and (6) continuity checks. All devices met the test requirements.
- (j) Temperature Electrical Cycle (14 units) - The devices were cycled at 24, 28, and 32 Vdc at +20° F and +165° F. All units cycled properly.

- (k) Function (14 units) - The S&A devices were fired at all four combinations of high and low temperature in the SAFE and ARMED positions. The conditions and specimens tested were:

<u>Test Temperature Position</u>	<u>No. Units</u>	<u>Specimen Numbers</u>
Low Temperature ARMED	5 units	1, 2, 3, 13, 14
Low Temperature SAFE	2 units	4, 5
High Temperature ARMED	5 units	6, 7, 8, 11, 12
High Temperature SAFE	2 units	9, 10

NSI detonators and CDF lines with aluminum tubing witness sleeves were installed for these tests. Debris Retainers MSFC PN 10A00487 were installed on the units fired in the SAFE position. Detonators were fired simultaneously using a pair of PIC Ground Ordnance Firing Assembly 17A10436. NSI detonators and CDF lines were installed and torqued in place. These assemblies were conditioned at +20° F or +165 °F for one hour. After conditioning they were removed to the test bay and fired.

All units functioned properly. On the ARMED position firings the detonation transferred across the explosive lead to the CDF line and CDF explosive cores detonated high order causing complete fragmentation of the witness tubes.

For the SAFE position firings detonation did not propagate to the CDF lines and there was no chemical decomposition of the CDF explosive core. Also there was no fragmentation

of the S&A rotor or body and the detonators were not expelled from the body. The explosive leads were initiated on all SAFE firing units. Small fragments ejected through the body vent holes were captured by the debris retainers. On specimen number 10, a fragment of the explosive lead ejected through the vent hole, punctured the debris retainer. However, this fragment did not fully penetrate the retainer wall but was contained.

Photographs taken of the various results are grouped as appendix A of this report.

The photographs and results are:

- #1 Typical S&A firing setup shown immediately after firing
- #2 Specimens from Low Temp-Armed Function
- #3 Specimens from High Temp-Armed Function
- #4 Specimens from Low Temp-Safe Function
- #5 Specimens from High Temp-Safe Function
- #6 Specimens #1 and #2
- #7 Specimens #3 and #4
- #8 Specimens #5 and #6
- #9 Specimens #7 and #8
- #10 Specimens #9 and #10
- #11 Specimens #11 and #12
- #12 Specimens #13 and #14
- #13 Debris Shields from specimens #4, #5, #9
- #14 Punctured debris shield and fragment from specimen #10
- #19 & 22 CDF end tips from SAFE firing units
 - #19 - SN 4
 - #20 - SN 5
 - #21 - SN 9
 - #22 - SN 10

5.3 PYROTECHNIC INITIATION CONTROLLER (PIC) AND CONTROL PANEL

For qualification firing tests the NSI detonators were initiated by a pair of 17A10436-7 Ground Ordnance Firing Assemblies provided by MSFC. These PIC's were actuated using a control panel constructed by TMC/S in accordance with figures 1 and 2 of pyrotechnic initiation controller operation and checkout procedure MSFC 17A10230 except that the 28 Vdc and 5 Vdc power supplies required were housed within the control module for portability and compactness. Firing cables were also fabricated by TMC/S using connectors provided by MSFC. Photograph #15 shows the PIC's, control module, and cables with a detonator resistance simulator installed on one of the cables.

Checkout of this system in accordance with procedure MSFC 17A10230 showed all the correct voltages and resistances and all NSI detonators fired on command during the S&A firing tests.

5.4 TEST MALFUNCTIONS

As mentioned earlier specimen numbers 2 and 14 malfunctioned after exposure to random vibration and ordnance shock respectively. The nature of the malfunction, investigative effort, cause, and corrective action are discussed herein.

5.4.1 Specimen Number 2

5.4.1.1 Description of Malfunction

Specimen number 2 was being subjected to ambient temperature electrical check out after Mission 1 random vibration. The rotor of the device over-rotated (rotated beyond 90) on an intermittent basis when cycled from the SAFE to the ARMED position. The device had cycled properly at 24 and 28 Vdc prior to malfunctioning at 32 Vdc. The circuitry checks confirmed the malfunction.

With the device in the ARMED position the contact test results for test positions G-H, J-H, K-N, and K-L were those that should have existed if the device were in the SAFE position. The overtravel, also visible by viewing the slotted end of the rotor, was measured at 12 degrees. The device was also tested and the rotor overtraveled at 31.5 and 31.0 Vdc but operated properly at 30.5 Vdc and lower.

5.4.1.2 Evaluation

The housing was removed by drilling out the spring pins and breaking the adhesive seal. The unit was opened, examined closely, and observed during operation. The condition was traced to an improperly drilled hole in clutch PN 817183 which was elongated (roughly oval shaped) to .081. Hole size should be .062/.065 diameter.

The spring pin pressed into this hole holds the driving clutch to the solenoid shaft. However the oversize condition allowed slippage between these components when the clutch arm impacted the detent arm so that positive detent action was not achieved. Photograph number 16 shows this condition with the elongated hole visible just above the detent roller.

A drop of epoxy was applied to the hole/pin and allowed to cure. The device was then retested at 24, 28, and 32 Vdc and it operated properly. It was operated for 40 consecutive cycles at 32 Vdc (ambient temperature) without evidence of malfunction.

No other deficiency was found and no other disassembly or tear down was performed. The housing was refitted to the body and temporarily sealed using fabric backed tape. Because the hermetic seal and the dry gas atmosphere within the unit had been disturbed temperature-humidity and leakage tests were not performed. Testing was resumed on this unit starting at electrical checkout. Temperature electrical cycle and low temperature function ARMED were subsequently performed and the unit functioned normally.

5.4.1.3 Conclusion and Corrective Action

Consideration of S&A operation indicates the malfunction occurred only at higher operating voltages which produce more rapid rotor rotation (typically 30 milliseconds at 32 Vdc versus 50 milliseconds at 24 Vdc) and therefore require more positive detent action.

Corrective action to prevent recurrence of this failure mode will be to:

1. Examine, repair, and if necessary replace the drill fixture used to match drill the clutch and solenoid. Incorporate a hardened drill guide/bushing into the fixture.
2. Revise instructions for inspection of the drilled hole and installation of the spring pin with specific instructions to assure the same condition does not exist prior to proceeding with assembly.

This corrective action will become effective for the next lot of units to be assembled.

5.4.2 Specimen Number 14

5.4.2.1 Description of Malfunction

During dynamic testing at Approved Engineering Test Laboratories (AETL), specimen number 14 failed to operate after being subjected to mission 1 ordnance shock applied in the Y axis, the first axis to be tested. The malfunction was failure of the device to cycle when the operating voltage was applied to the ARM command circuit. The voltage drop circuitry tests indicated an abnormal condition associated with the ARM COMMAND circuit which is controlled through switch S2.

5.4.2.1 Description of Malfunction

The circuitry test results with the device in the SAFE position were:

<u>Circuit</u>	<u>Normal Reading</u>	<u>Actual Reading</u>
Pins K-N	Less than 750 mv	Open circuit
Pins K-L	Open circuit	220 mv

Therefore, values obtained were normal for a device in the ARMED position. However, monitor circuits and visual indication showed the device to still be in the SAFE position.

5.4.2.2 Evaluation

The defective unit was returned to TMc/S for examination. The housing was removed by drilling out the spring pins and breaking the adhesive seal. Visual examination showed switch S2 to be in the energized (plunger depressed) position which was normal for a device in the SAFE position. However continuity existed between switch terminals C and NC and an open circuit existed between terminals C and NO. These readings were normal for an open (plunger released) switch but incorrect for a closed (plunger depressed) switch indicating that the switch was either damaged, or had otherwise malfunctioned.

When the rotor was rotated manually, alternately releasing and depressing the plunger, the condition corrected itself. Circuitry checks were repeated and all readings were normal. Operating voltage was re-applied and the device operated normally thereafter indicating improper switching action rather than switch damage.

The housing was refitted to the body and sealed in place using fabric backed tape. Because the environmental seal and dry nitrogen atmosphere within the device had been disturbed temperature-humidity and leakage tests were omitted. Testing was resumed starting

5.4.2.2 Evaluation (Continued)

with electrical checkout. Ambient temperature electrical checkout and temperature electrical cycle (paragraph 4.3.10 and 4.3.11 of MSFC 10A00465) were completed with no further indication of switch malfunction.

When the electrical tests were completed, switches S1 and S2 were removed from the device. The rotor was manually rotated to the ARMED position for the function test. This unit was fired in the low temperature ARMED mode and functioned properly.

Switch S2 was opened by carefully cutting away the plastic wall exposing the interior for examination. This switch was manufactured by MICRO SWITCH CO. and is identified as their PN 2LSX39-T. It is listed on Qualified Products List QPL-8805-30 qualified to MIL-S-8805/4 as PN MS24547-1. The moveable blade of this switch is a bifurcated design jointed just outbound of the point of contact of the plunger. Photograph number 17 shows the moveable contact in the normal (correct) position with the plunger depressed which duplicates the plunger position at the time the ordnance shock impacts were applied. It was found that a very light pressure on the outboard segment of the blade would cause it to slip at the joint allowing it to contact the incorrect terminal. The blade/contact would remain in this incorrect position until a counter force was applied to return it to the correct position. This condition is shown in photograph number 18.

During the ordnance shock test in which the malfunction occurred switch S2 was oriented so the applied shock was in the same plane and in-line with blade movement. This would be the most vulnerable switch position in terms of "auto-displacement" of the blade. No contamination by foreign material, evidence of wear, or damage was found. Therefore the preliminary conclusion was that the ordnance shock pulses which reached a peak of 3,500 g's caused the outboard segment of the blade to move into and remain in the incorrect position until subsequent actuation caused it to return to the correct position.

5.4.2.2 Evaluation (Continued)

Investigation of the failure continued with examination of another switch of the same MS24547-1 part number, manufactured by CUTLER-HAMMER INC. The CUTLER-HAMMER switch uses a one piece blade which appeared to be less susceptible to the apparent failure mode. A pair of these switches with actuators were installed on an S&A body and the switch adjustment procedure was followed. The same characteristic switching action was obtained for these switches as was observed in the MICRO SWITCH unit, that is the switch could be made to snap over and remain in either position against the depressed plunger at a finite position in the differential travel zone. Further examination and manipulation revealed that the condition created is not a switch malfunction but results when the plunger is depressed just beyond the pretravel (snapover) range but is not sufficiently depressed into the overtravel range. That is, the switch is not fully actuated. The switch adjustment technique used on the qualification lot was to position the switches using monitor lights that indicate immediately when snap action occurs. No provision was made to assure that the switch plungers were fully depressed and in fact initial plunger deflection (slack or pretravel taken up) was avoided.

The same action of borderline actuation versus full actuation was observed on the switch removed from the failed unit but the dependance on adjustment was not confirmed until adjustment of the CUTLER-HAMMER switches was performed.

5.4.2.3 Conclusion

Our conclusion is that in specimen number 14 switch S2 was not properly assembled and adjusted but rather that borderline actuation was obtained. Under normal handling, checkout, and even under lower level dynamic testing the switch actuated properly. However the 3,500 g impact of the ordnance shock test was sufficient to cause the switch to snap over.

5.4.2.4 Corrective Action

We recommend that MICRO SWITCH part number 21SX39-T qualified in the S&A device be retained as the qualified part and that recurrence of the observed failure mode will be prevented by a specific, positive adjustment of the switches during the assembly operation. Full actuation of the switch plunger can be readily observed visually and verified electrically and will be made a part of our manufacturing instructions.

No additional component testing is necessary since visual and electrical verification of switch adjustments can be performed on each device at any time prior to installing and sealing the housing to the body.

5.4.3 Summary

Two test malfunctions were experienced during qualification testing. The first, an electrical cycle malfunction, was traced to an improper manufacturing operation, a condition which will be prevented by more careful assembly and examination.

The second condition, a switch malfunction, resulted from improper assembly and adjustment. This condition will also be prevented from reoccurring by refined adjustment and examination. Neither condition resulted from a design or material deficiency.

5.5

PROGRAM SYNOPSIS AND CONFIGURATION

5.5.1

Program Synopsis

The overall program was completed with a minimum of problems particularly in view of the complexity of the S&A device. No significant design problems were encountered during development. Tests of the most critical design parameters and test environments did not reveal any basic design problems. Deficiencies which occurred required only dimensional corrections and refined assembly processes/instructions to correct. These corrections were incorporated into the build-up of qualification devices.

Fabrication and lot acceptance testing showed that a greater margin for operating voltage was required in order to meet performance limits at temperature extremes. Readjustment of solenoid/springs and more diligent adjustment and alignment of the drive components corrected operating deficiencies which occurred during high temperature cycling tests.

Two qualification test malfunctions were experienced. However they were not the result of design deficiencies and are not sensitive to the multiple mission environments but resulted from improper assembly and adjustment. The critical performance and functioning requirements were totally successful. All ARMED function test firings caused high order detonation of the CDF lines as required. All SAFE function tests were successful with no decomposition of the CDF test lead and no fragmentation of S&A rotor or body.

Therefore, we believe that Safety and Arming Device MSFC 10A00465, TMC/S PN 816780 has successfully passed the complete qualification test program and is qualified for ten missions of flight on Space Shuttle Solid Rocket Booster.

5.5.2 Configuration

The following Indentured Data List (IDL) and drawing tabulation represents the gualaified configuration.

IDL	816780 L	817183 A	817190 B
DWG	816780 E	817176 C	817186 B
	817170 NC	817189 A	817173 NC
	817171 C+VCO 13815	817181 B	817187 NC
	817166 NC	817177 A	817330 NC
	817174 A	817169 NC	817179 NC
	817334 B	817184 A	817178 NC
	817185 NC	817180 B	817172 B
	817216 NC	817182 C	817367 NC
	817191 A	817168 NC	817188 A
	817331 B		

APPENDIX A

PHOTOGRAPHS

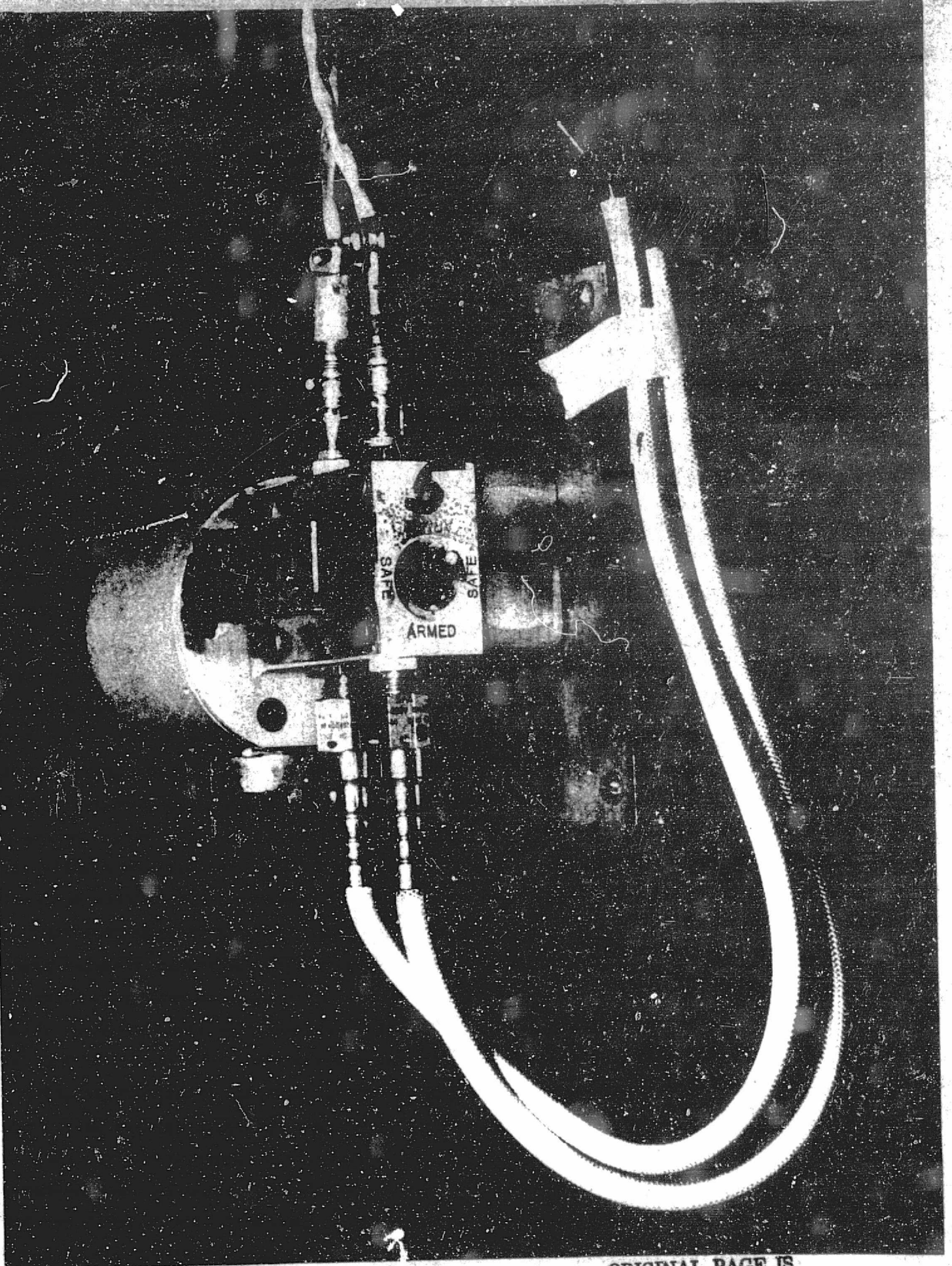


PHOTO #1

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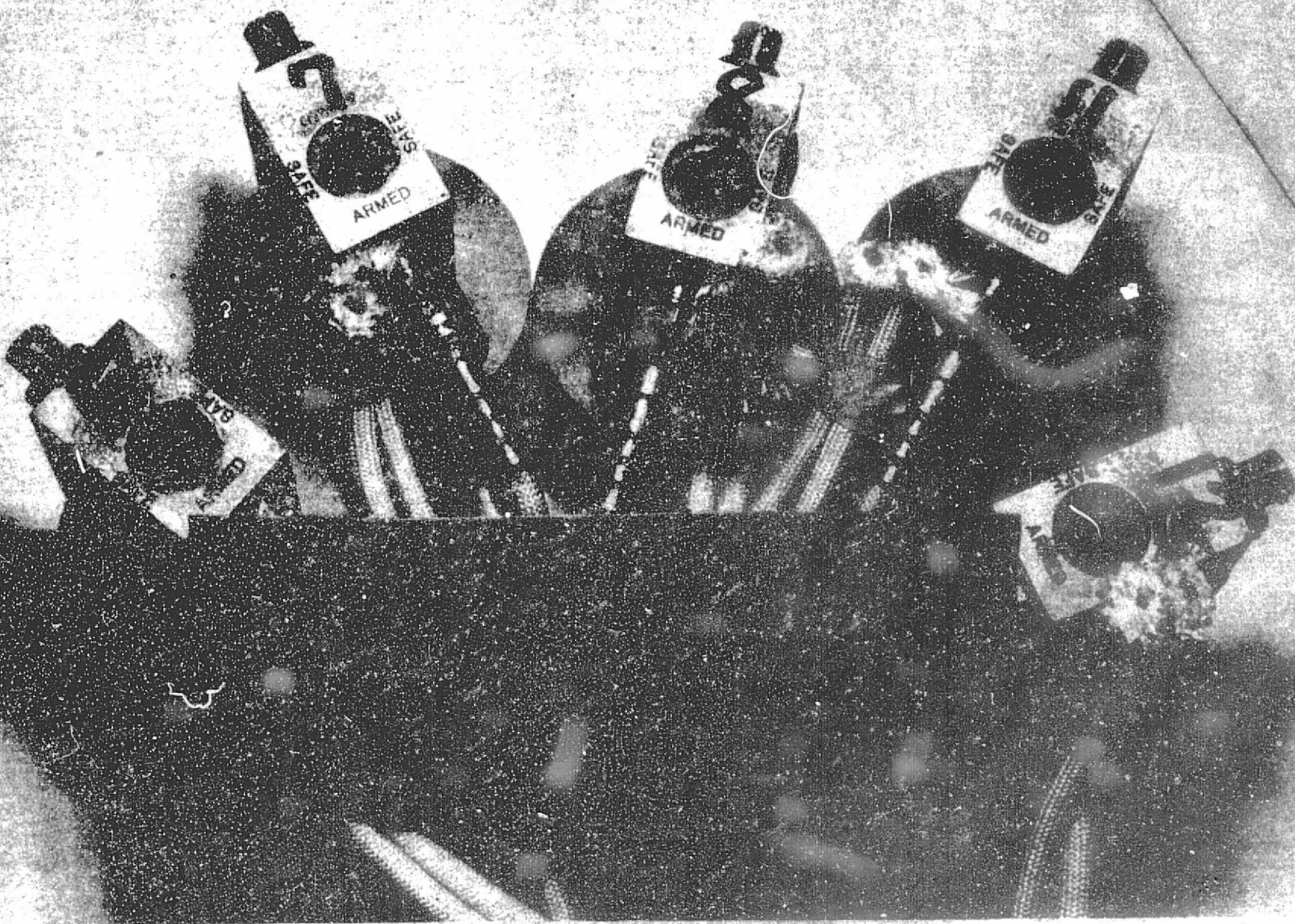


PHOTO #3

PHOTO #4



UNITS

4,5

SAFE

+20°F

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PHOTO #5

UNITS 9, 10
SAFE +165°F

SAFE & ARM DEVICE

SPECIMEN # 1

ARMED +20°F

SAFE & ARM DEVICE

SPECIMEN # 2

ARMED +20°F

WIRE DEVICE

#3

SAFE +20°F

10860

10860

10433

WIRE DEVICE

#4

SAFE +20°F

10433

SAFE & ARM DEVICE
SPECIMEN # 5
SAFE +20°F

SAFE & ARM DEVICE
SPECIMEN # 6
ARMED +165°F

SAFE & ARM DEVICE
SPECIMEN # 7
ARMED +165°F

SAFE & ARM DEVICE
SPECIMEN # 8
ARMED +165°F

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SAFE & ARM DEVICE
SPECIMEN #9,
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SAFE & ARM DEVICE
SPECIMEN #10
SAFE +165°F

SAFE & ARM DEVICE
SPECIMEN #11
ARMED +165°F

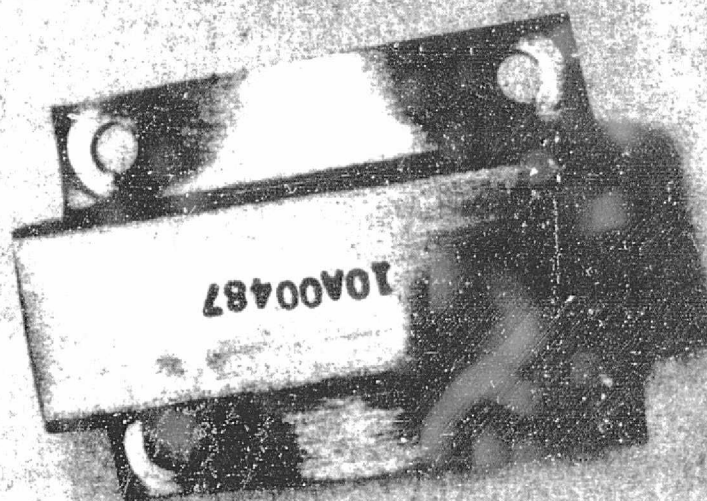
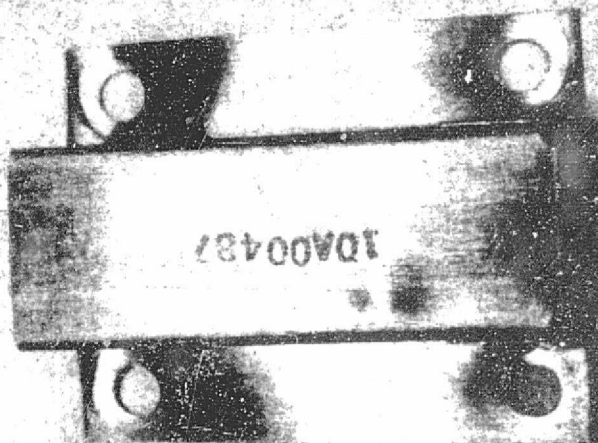
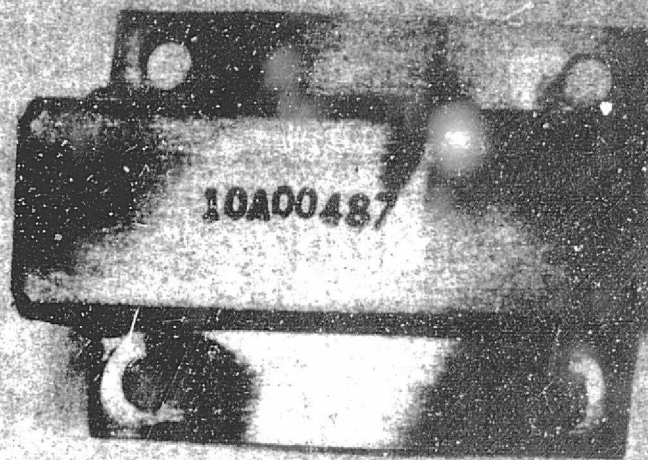
SAFE & ARM DEVICE
SPECIMEN #12
ARMED +165°F

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SAFE & ARM DEVICE
SPECIMEN #13
ARMED +20°F

SAFE & ARM DEVICE
SPECIMEN #14
ARMED +20°F

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SAFE AND ARM DEVICE

Specimen #10

High Temp - SAFE Position

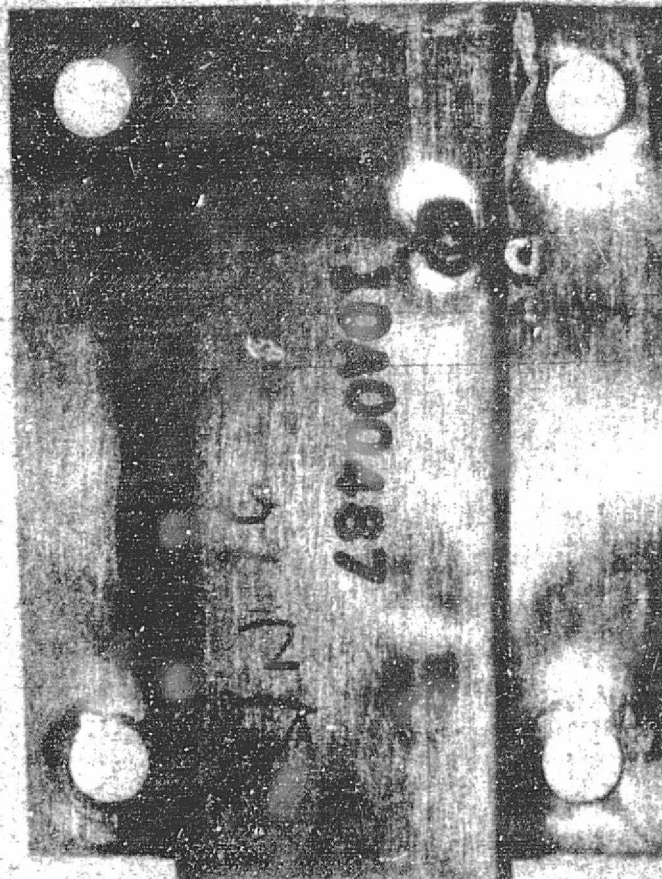
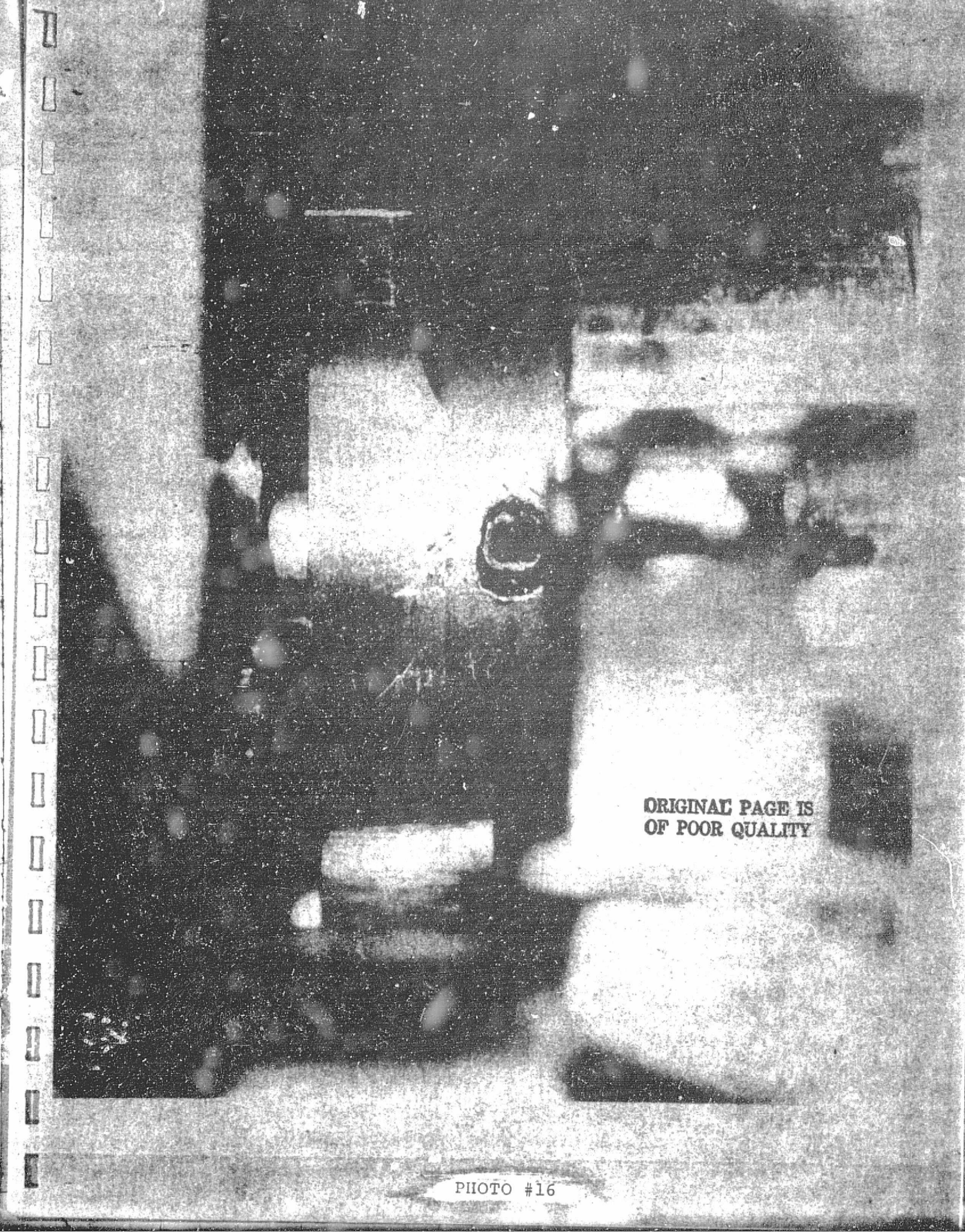


PHOTO #14

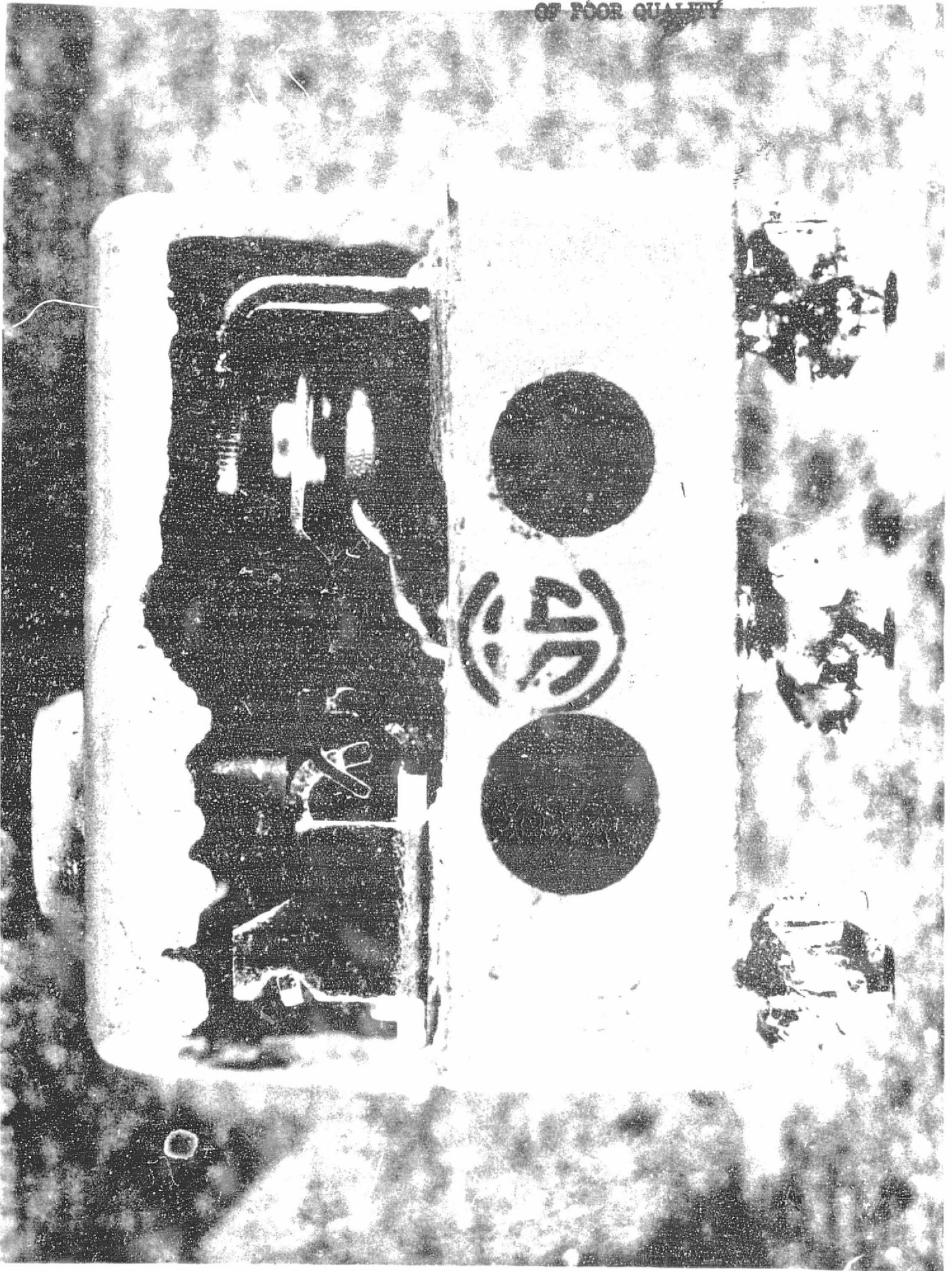
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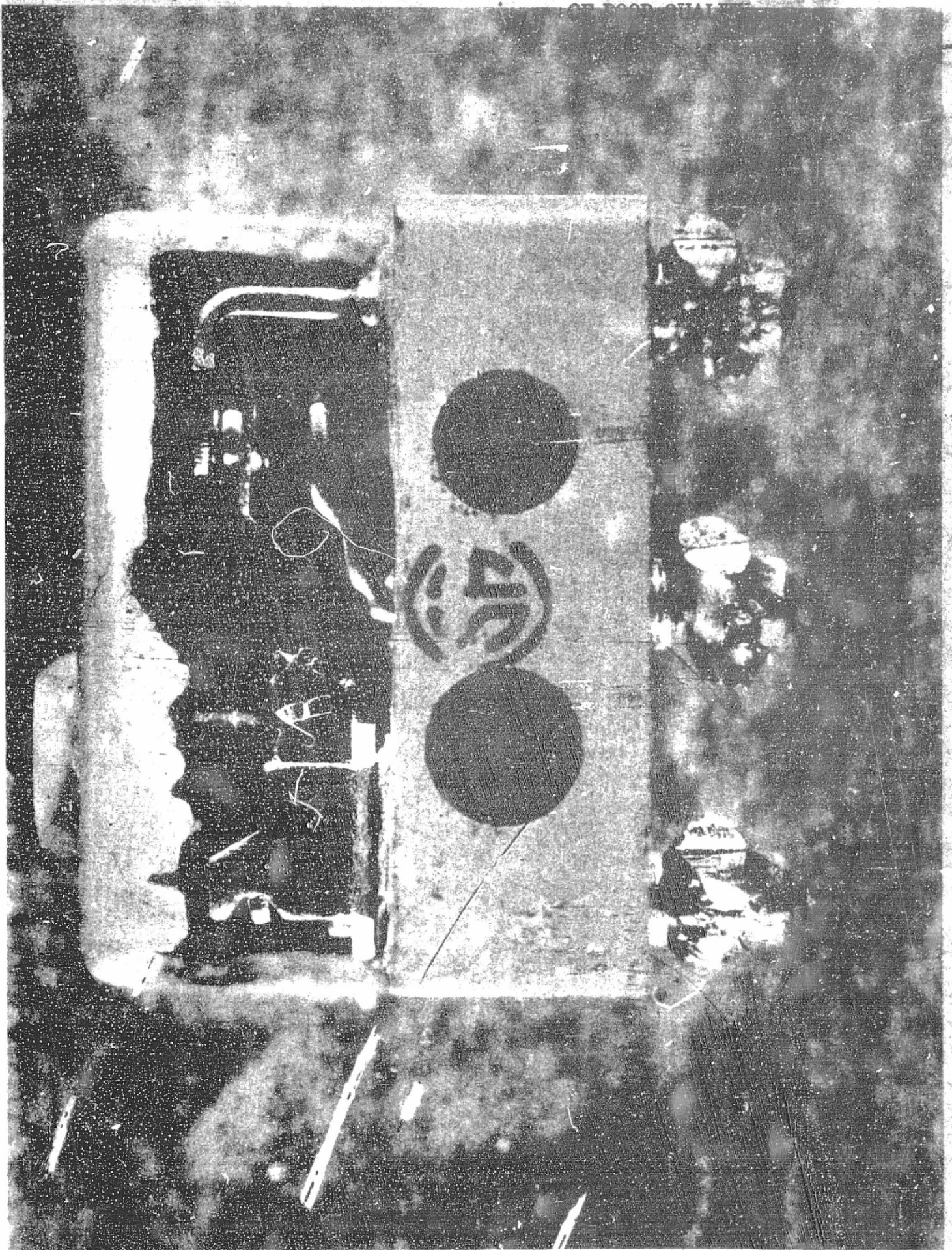
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PHOTO #20



PHOTO #21



PHOTO #22